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POLICY-FORMULATION INTERROGATION NETWORK

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Roy Amara and Paul Baran

The Institute for the Future is a not-for-profit organization concerned with the development of long-range forecasting and planning tools. In March 1972 it undertook a two-year effort to improve the state of the art of on-line interactive systems for the extraction and processing of group judgments. The initial work converted manual, anonymous, and paper questionnaire interrogation procedures into an interactive terminal process. The next steps broadened the capability to allow greater ad hoc flexibility during the inquiry and permitted conduct of structured on-line interactive conferencing via terminals.

The present organization of an inquiry uses two teams: an inquiry management team and a group of "experts" or participants. The inquiry management team consists of a chairman (who is the executive with a problem that he wants help in solving), an umpire (who acts as the arbiter for procedural matters), and one or more editors (who perform language modifications of the respondents' inputs). For example, the editor indicates which inputs constitute implicit action motions, eliminates misspellings and duplicate entries, and deletes remarks that add no new information to the inquiry--such as prejoritive comments on opposing viewpoints.

The executive faces the problem of knowing which of his "experts" to believe and how to combine their inputs, if they each have different perceptions of possible outcomes in an inquiry. Thus, the executive seeks to have the experts critique one another's judgments to determine where consensus exists, where it does not, and the reasons for the differences of opinions.

The system being used is the PDP-10 at USC, operating under TENEX via ARPANET. Much of the work to date has involved the routine programming of a series of modules to perform those operations most commonly encountered in structured inquiries where anonymity is useful. The third release of the programming has been completed, and enough additional modules are scheduled so that the contents of the next two releases are now defined.

The system will be capable of several modes of operation. It will provide for operating in a semi-off-line manner to allow respondents to answer long questionnaires at their leisure. It will also allow a full synchronous or real-time mode necessary for a single group conference.

A modified Robert's Rules of Order control procedure is planned as one of the several modes of the system's operation. (Conventional Robert's Rules are designed for fully serial inputs and assume that the subject matter can be decided solely on a binary decision basis, i.e., a vote "for" or "against" a motion.) The extensions being developed include the capability to handle shades

of gray decisions, the means to present the groups' opinions in rapid graphical formats, and, of course, the means to preserve the anonymity of the respondents.

To achieve the goal of developing a useful management tool (where usefulness is defined as the willingness of the participants to use this procedure in preference to others, such as face-to-face conferences), it appears almost necessary to have an operationally invisible interface between the participants in the inquiry and the computer-aided chairman of the inquiry. This is not easy as the participants must be assumed to have minimal familiarity with the system, to feel basically uncomfortable in the presence of the computer, and to have little time to waste in the inquiry. At this time, it is not at all clear that we will be able to program the system in a sufficiently comfortable manner for neophyte users so that real-world experts and senior personnel will willingly subject themselves to using this system in lieu of face-to-face meetings.

The system now being programmed is reaching the approximate level of performance of existing systems of this type. Our work seeks to continue and extend these early efforts to a new level of performance. But there is a limit to the degree of comfort of interaction possible by an inexperienced user trying to express himself via a computer terminal. While still focusing on improving the comfort level, or at least reducing the high frustration level, it is becoming increasingly clear that the conventional computer terminal alone may not suffice. One or more additional media inputs may be necessary to allow the respondent the degree of freedom he needs in order not to feel excessively constrained by the system.

Therefore, the role of voice conferencing (but not presently via the ARPANET) is being examined as an adjunct to the computer terminal system at this time; later, we may also look into FAX inputs and handwritten inputs. Preliminary work has begun by exploring the technical details of a suitable computer-controlled voice-conferencing system using the DDD telephone network.

In short, we are far from achieving our stated goal. Our work is progressing steadily, but no significantly new ground has yet been plowed. The degree of discomfort at the terminal interface is still unacceptable, and the system's present value as a management tool is still minimal. However, we are only nine months into the project. A lot of hard work remains.

ANALYSIS OF TECHNICAL AND POLICY OPTIONS IN THE FUTURE EVOLUTIONARY DEVELOPMENT OF THE ARPANET

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Principal Investigator:
Paul Baran

This project is tentatively scheduled to commence in early 1973 and will explore a range of alternative options open to the future evolutionary development of the ARPANET. In particular, the issue of divestiture will be considered and specific plans of action for such an alternative will be examined in detail.

There are a number of issues, including regulatory, technical, and economic possibilities and constraints that are to be addressed in detail for each of the possible policy alternatives to be considered. This investigation will seek to insure that due priority is given to the consideration of the needs of the research community now using the ARPANET so that any eventual transition is carried out in an orderly manner, without disruption to on-going research activities.

The basic goal sought in this project is that of creating a specific plan of action that will provide the greatest long-range benefit to the nation in return for its past, present and future involvement and investment in the ARPANET.

The project will start with a set of structured interviews with those having both an understanding and a specific interest in the ARPANET (including representative views of the attendees of this ARPA/IPT Principal Investigators Annual Meeting.) Interviews will also be conducted with the carriers and potential new carriers, as well as with other interested entities and agencies to insure that the full range of viewpoints of all affected parties is considered in the process of developing an organized set of alternatives.

Much of the work in this project will be that of detailed consideration of the alternatives viewed from different dimensions, including: technical desirability, regulatory constraints, management effectiveness, legal constraints, economic factors, and the specific impacts upon each affected community of interest.

All policy decisions that result from this work will be the responsibility of ARPA/IPT. This work is intended only to provide ARPA with background policy research to facilitate their policy-making role.

Computer Systems
Laboratory UCSB
Roland F. Bryan
8 January 1973

OVERVIEW OF UCSB's IPT RESEARCH IN NETWORKING-1972
(Detailed in CSL Reports)

SERVER AND USER SITE DEVELOPMENT
(Mark Krilanovich)

Simple Minded File System (SMFS) - This file storage facility was initially developed by Jim White for short-term storage on a 2314 resident disk (#122)*. Recently SMFS has been reshaped with Network login, control features, accounting, and storage mapping (#431). It has become a resource for general network use (#409). The present UCSB link to SMFS is now being replaced by the Network standard FTP. SMFS is also the basis for a more complicated network file service that will be completed in 1973.

Remote Job Service (RJS) - The network standard RJS has been put into service at UCSB. In addition, alternatives such as a link to HASP and a user oriented syntax have been made available (#436).

Network Control Program (NCP) - The NCP for IBM 360 continues to be refined for better efficiency and control. Methods of billing, reporting, and new handles to allow the easy appendage of service routines have been added. This NCP has served as a guideline for each new 360-type host that has joined the Network.

User TELNET - Links to the Network were provided to allow use of local Tektronix and IMLAC terminals. These terminals are used by the UCSB research staff in their Network activities, and have been instrumental when UCSB assists other sites in Network software development or diagnosis.

GENERAL NETWORK SUPPORT AND GRAPHICS
(Ed Faeh)

Data Reconfiguration Service (DRS) - Initially developed in conjunction with RAND this service will assist in the inter-communication between dissimilar systems on the Network. DRS has been checked out and used in local applications. It is now available for use by the Network at large (#437).

Network Graphics - The UCSB On-Line System (OLS) continues to serve as a test-bed for Network graphics development. Depending upon the UCSB socket number specified, a wide-range of terminal support exists for the user (#398). Tektronix 4002, 4010, and 4013 as well as IMLAC terminals may be used with various I/O formats. Level 0 Network graphics Protocol is also supported. Several IMLAC support packages were written in conjunction with MITRE.

Distributed File System - Work continues on this system in conjunction with MITRE. Files are stored at UCSB, UTAH, and BBN with the control program located at RAND. One-time diagnostics have been implemented at UCSB to assist in locating problems with this as well as other developmental systems.

*Refers to RFC number.

NETWORK APPLICATIONS AND EVALUATION
(John Pickens)

Using the Network - Automatic login and data conversion programs were developed on the User level of the UCSB On-Line System (OLS). These programs have allowed local Network users to readily login to Network sites, to bring data from other sites for hard copy printout, or as in the case of data from the Network Measurement Center, plot measurement data graphically on the OLS.

File Transfer Via TELNET - Utilizing the programs referred to above, in concert with TELNET, UCSB users have moved files and batch processing jobs between various sites on the Network. Early in 1971 file transfers between 10X and local O/S Data Sets were accomplished to assist NASA-AMES. Subsequent experimentation has allowed comparative testing to take place by running jobs at UCLA with results returned to UCSB. This work has been basic to standard FTP development, now nearing completion at UCSB.

Evaluation - A test group, formed early in 1971 used a multi-console classroom at UCSB to perform a prolonged assessment of the problems encountered by new users. Their critique and recommendations were summarized with the result that changes have been made at various nodes to assist users (#369).

Seminars and Demonstrations - Seminars have been given locally and at other ARPANET sites on Network applications. Recent ICCC participation demonstrated the use of Tektronix and IMLAC terminals attached through the Network to UCSB (NIC #12529).

SPEECH AND SIGNAL PROCESSING
(Larry Pfeifer, David Retz, John McAfee)

Speech Recognition and Data Compression - Techniques for single speaker identification by phonemic representation and reduction of the bandwidth needed to transmit continuous speech were developed using the waveform analysis approach. This project was discontinued in mid-year; however the legacy has been both hardware and software that link an SEL 810B signal processing system to the Network by way of the 360 Host.

Interactive Signal Processing System - In support of speech analysis an interactive Culler-Fried On-Line System with graphics console was adapted to signal processing. A high speed link to the 360 plus attachments to abundant disk and drum storage were designed and implemented. This facility was used for speech analysis and is now being employed for Network Conferencing and Data Channelizing experiments. Techniques for integrated speech and data transmission over low-bandwidth connections are being developed.

DIRECT SUPPORT TO OTHER NETWORK SITES
(Art Berggreen, Don Shook, David Retz, John McAfee)

Very Distant Host Development (VDH) - The specification and design of a VDH connection for use by SCRL on their PDP-11/20 has been completed. Installation of the new hardware and diagnostic software will take place this month.

IMP Attachments for 360 Systems - This hardware interface went through one last modification to convert latent discrete components to integrated circuitry early in 1972. Units were supplied to MIT, NASA-AMES, USC, and UCSB. Orders have been received from AFTAC and RAND.

INTRODUCTION 1

It is relevant to summarize the basic terms of ARC's current contract with IPT; they were settled upon in June of 1971, and have essentially been in effect through the calendar year of 1972: 1a

> Our work is focused entirely on developing and delivering certain types of operational services through the ARPANET -- we are explicitly broadening the range of our work beyond exploratory development to include special, exploratory-application forms both of service/product development and of operational service support. 1a1

The services are to support exploratory application of the intellect-augmentation techniques whose evolution and transference to users are the central, continuing vector of the Augmentation Research Center. We are now using the term, "Computer Based Knowledge Workshop" (or simply, "Workshop") to refer to the coordinated system of augmentation techniques within which the "knowledge worker" (who is our end-user target) does his "knowledge work. In the contract, the specific service items listed were: 1a2

- The Network Information Center (NIC), 1a2a
- Dialogue Support 1a2b
- Documentation Production and Control 1a2c
- Software-Engineering Augmentation 1a2d
- System-Developer's Handbook 1a2e
- System-Developer's Baseline Management 1a2f
- Collaborative System Evolution 1a2g

NOTE: A different and perhaps more useful categorization of the Workshop services we now consider is described in in the Paper, "Coordinated Information Services for a Discipline- or Mission-Oriented Community," by D.C. Engelbart, 12 Dec 72 (Available from us under ARC/NIC No. 12445, and also to be published in the Proceedings of the Second Annual Computer Communications Conference, San Jose, California, 24 Jan 73). 1a2h

For each category of Workshop service we proposed three primary aspects among which we would expend development energy: 1a3

- Functions -- the repertoire of transactional capabilities, their functional effects, and the control language and protocol involved in each service; 1a3a
- Delivery capability -- the means and techniques that support delivery of such functions to remote users, who would need support from both computer and people services; 1a3b
- Marketing capability -- the means and techniques for setting up and evolving the service-support arrangemnts, within the shifting, experimental environment of the Network community, for interested groups to actually try integating our services into their work. 1a3c

IPT support is divided as follows: 1a4

- Forty percent for the NIC, for both development (of function, delivery, and even a bit of marketing), and for the operational marketing and delivery of its services. 1a4a
- Sixty percent, for developmental work only, in the other service categories -- it being understood that any subsequent operational business in marketing and delivering "workshop support" services to subscribers would be a separate business matter beteen us and the subscribers. 1a4b

Our aim is not at all to remove ourselves from the exploratory R&D business; rather we are investing in a strategy that is aimed at several results: 1b

- To experiment with new means for consciousy pursuing socio-technical innovation; 1b1
- To experiment with new ways in which discipline- or mission-oriented communities can do their work; 1b2
- To exercise the ARPANET in its experimentation with the sharing of distributed computational and data resourcesd; 1b3
- To demonstrate that perhaps the most important resources made "sharable" by a multi-access computer network will be

those represented by the elements of knowledge, skill, judgement, intuition, conceptual skills, etc. distributed among the humans in the Network community; 1b4

To promote a more significant and efficient exploration of workshop augmentation needs and possibilities -- among a variety of application groups who can share in the use of a solidly supported base of Workshop-support tools and services, and who can each contribute in important and gratifying ways to the continuing evolution of that workshop base. 1b5

WORKSHOP UTILITY DEVELOPMENT 2

For the past year we have been working toward the establishment of what we call a Workshop Utility service. Its basic, computer-support component is to be furnished through the ARPANET by a TENEX facility at the site of a commercial time-sharing company, who will install, maintain, and operate the facility under contract to us. We will maintain in that facility an especially solid, less-experimental version of NLS, and we will take contracts for its usage. 2a

We sent out an advertised RFP, and ended up with four companies submitting proposals. From among these, we have selected TYMSHARE for next-stage negotiation. Concurrently, we are actively seeking clients to subscribe to the Service -- offering service modules that are fixed proportions of the Utility's computer capacity over a one-year period. Our tentative plan is to launch this service about September, 1973. Along with each portion of NLS computer service, the Workshop Utility will include a certain proportion of technical support. 2b

We aren't going commercial with this enterprise; this is but a step, consistent with the contract provisions described above, toward the aims outlined in Branch (1b). We are looking only for clients of the Workshop Utility who plan to use it in the exploratory mode -- to apply it in prototype applications where it is to their advantage to experiment with a solidly supported but still early model of an augmented Workshop, and/or where it is to our advantage to have their particular experimental applications providing a special kind of orientation, stimulation, feedback, etc. to the benefit of the ongoing Workshop evolution. 2c

The experience and developments outlined below for this past year are all very much relevant to increasing our ability to

support a Network Workshop Utility, and to increasing the value of that Utility to serious-user clientele. 2d

OPERATIONAL RELIABILITY AND EFFICIENCY 3

Toward these ends we have been investing at least ten percent of our manpower. We have experimented with roles and procedures, with maintenance schedules and policies, and with software conventions and practices. We implemented a relatively comprehensive operating-system measurement system (SUPERWATCH) for TENEX, and have been learning very useful things from analysis of the measurements. 3a

For over six months a seasoned operations research man has been studying both the SUPERWATCH measurements and our user operations; he is helping us understand the dynamics of our service loading, and he has been the architect of a plan involving grouping and resource allocation at an organizational level, together with special TENEX-schedular conventions and practices, for partitioning and scheduling loads and service. This is an important step toward understanding how to provide sophisticated computer services in a Workshop environment. 3b

DISTRIBUTED-SERVICE EFFORT 4

Serving a distributed user clientele is a basic problem for any Network Service; and we have been struggling and learning with/about problems and needs. An overwhelmingly strong impression we now have in this respect is that, until the services available to them (including their terminals and their way of using them) become integrated into their way of life like the telephone system now is, the distributed clientele of a powerful computer-support system won't successfully become established or make significant use of the service without a very active effort explicitly involving personal contact and a goodly amount of direct personal support. 4a

This realization has affected our development priorities, and will be reflected as much as possible in the operational services of the Utility. For example, we have known that remote availability of DNLS (Display NLS) would ultimately be very important, but for the NIC we had assumed that most of our clientele wouldn't have the terminal equipment to make use of it, and therefore NIC service has concentrated quite a bit on TNLS (Typewriter NLS). 4b

A workable network DNLS was eventually developed in time for the ICCC (with specially programmed IMLAC terminals, and thanks to generous last-ditch push by Peter Deutsch of Xerox). 4b1

We have for some years had DNLS features that allowed people at two different consoles to link screens, and by simultaneously talking on a telephone they could collaborate as though standing together in front of a (very special) blackboard. For the ICCC, we made the necessary modifications so that this feature would work on the IMLAC terminals, too. 4b2

Subsequently, we have used this feature to work with people at RADC (in Rome, New York), who are just beginning to experiment with Network-supported DNLS. This shared-screen mode of dialogue turned out to be such a powerful means (dramatically so) of providing direct personal support, that it makes clear to us that every Workshop Utility client site should be equipped with at least one DNLS terminal to support this kind of direct, personal help from the Utility (not to speak of the significant value for use in tele-conferencing dialogue among fellow Workshop Utility clientele). 4b3

Among the other developments we made toward improved, distributed service were the following: 4c

Special means for directing formatted-page output to local printers tied to a TIP, including page at a time delivery to typewriters not using pin-feed paper. 4c1

A very-simple "query" interface to NLS files, allowing search through NLS reference files (especially the NIC locator set) with essentially no training (except for how to reach us through the TIP and how to log into TENEX). 4c2

Improvements to the IDENT and distribution facilities of the NIC Journal. 4c3

A highly automated process for producing NIC catalogs 4c4

Close involvement with development of the Network File Transfer Protocol -- which is an important ingredient in the kinds of information services both NIC and the Workshop Utility will offer. For example, to transfer files generated from other editing systems into the Journal for distribution, cataloging, and archiving; or for delivering

online Journal memos to the recipient's site for printout; or for using special Network file-management resources to store our ever-growing collection of online material. 4c5

WORKSHOP FUNCTION DEVELOPMENT 5

Professional-quality, computer-typeset publication via our Output Processor and a commercial service bureau (using a III Comp-80) has been a steady development activity with us. We are now setting up for publishing our NIC documentation this way, and also struggling as amateur typographers to set up our latest project report. 5a

The typography-control directives added to the Output processor give us such a wide choice for type of font, size, density, and page position, that the early experiments produced very wild results. That serious typography is a full profession can readily be appreciated. 5a1

When he gets to the final type-setting pass in producing a manuscript, almost every client of the Utility will clearly need specialist help if he deviates much at all from some standard format for his type of material. The ability to obtain such help from a remote specialist, via real-time telconferencing using the shared-screen dialogue, is a beautiful example of the benefits the Network will bring for human-resource sharing. 5a2

Economical generation and updating of online files, whether for document development or data management, is another thing in which we have been steadily investing. 5b

We have continued a low-grade effort, recently stepped up, to evolve what we call DEX (for Deferred Execution system) as a supplementary Workshop facility. We currently spool the input from online-type typewriters onto magnetic cassettes. Paper tape works, too, and likely the clerical support for a cluster of knowledge workers would find a mini-computer, working in a low-feedback spooling mode, effective for DEX-input purposes. 5b1

Almost the whole range of NLS functions are specifiable, and the logic of the batch-executed DEX control processes has been developed to put the burden on the run-time "compiler" to worry about what the current address of a target item might be, in view of the alterations specified up to this point in this batch entry. 5b2

I claim that a skilled clerk-typist will learn DEX very handily, and can be significantly more efficient in terms of keyboard time and computer-resource consumption, for many basic types of file-development work, than the most-skilled DNLS user. We discovered many years ago that in an important number of cases involving heavy reworking of manuscript drafts, it was an advantage to have DEX-like systems that didn't talk back to the operator; to make use of the feedback took the operator's attention away from the input material, and for later scanning of the typed-input record the feedback typing represented distracting "noise". 5b3

Calculation is a basic sort of Knowledge Workshop task. For heavy computation our Workshop would provide useful support in formulating, studying, documenting, etc. of the models and computer programs, but we would count on shipping the computation out (through the Network) to systems that were built to do that kind of work. 5c

But in the range covering needs where people now turn to slide rules, little desk calculators, and perhaps to the simpler applications of BASIC programs, it is feasible and valuable to include special calculation-support tools in the Workshop environment. We have been working on such as an addition to NLS. Early developments in this regard demonstrate immediately that they can be extremely valuable. 5c1

NETWORK INFORMATION CENTER 6

Although the qualitative nature of NIC-service functions has changed but little during the year, we have learned a great deal, have developed substantially more reliable operational support, and improved efficiencies. We have taken over the job of maintaining the Network Resource Notebook that was effectively begun by BBN, and are pushing heavily upon extending the scope, depth, and accuracy of its coverage. Our information-ouput service load is still predominntly offline, and involves a lot of NIC-staff interaction with clients: We have 132 addressees to whom we mail regularly, about five items a week (54 Network Liaison people, 46 Station Agents, and 30 Associates -- individuals who aren't ARPANET but who are involved actively in network technology). 6a

We maintain special circulation lists (full addresses, telephone numbers, etc) and provide online or hard-copy distribution of intra-group memos to 15 special-interest groups, four of whom are becoming quite active in using this

mode of dialogue: The ARPANET Sattelite Systems Group (18 members), the Computer Based Instruction Group (26), the International Network Group (29), and the Speech Understanding Research Group (26). 6b

We are beginning an interesting experiment with ACM's AI SIG, who have for some time been publishing a newsletter in a conventional manner. They have taken steps to use the NIC Journal to get early releases of articles put online and to facilitate online commentary. We hope ultimately to be able to support their direct publication from online files. 6c

We maintain relatively comprehensive "ident" data for a total of 366 registered indiviouals, affilliation organizations, and working groups, and somehow have a telephone directory with 530 phone numbers. All of these data are accessible via DNLS and TNLS, and much of it with the very easily used QUERY subsystem. Updating these data is a religiously maintained activity. 6d

NIC monthly pays a telephone bill of about $700, and a mailing bill of between $400 and 1300; it also runs about 5000 sheets a week out of its own Xerox machine, besides paying about $300 per month for outside reproducton costs. 6e

Each Station Agent requires special introductory help; only a few have been sent to SRI to learn -- most of them have a lot of telephone talk at first, and we try to call them regularly to check up on things. We have run about seven TNLS classes, and one DNLS class, at our site; and have been learning about off-site teaching with the group at RADC. 6f

We invested very heavily in ICCC participation; many people (more than just our NIC group) worked for three to five months preceding the Conference, and twelve of us spent the week in Washington. We considered the event to be highly successful, and very much worth whatever we all spent on making it come off. 6g

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NIC 13541
8 Jan 73

RESEARCH IN THE ANALYSIS AND DESIGN OF LARGE SCALE NETWORKS

Network Analysis Corporation's contract with ARPA has the following objectives:

- The development of data handling and computational techniques to deal with massive DOD network analysis and design problems.
- The study of the use of display devices to allow humans to interact in the computer design of networks when using heuristic procedures now applicable only on a remote batch basis.
- The study of the properties of large packet switched computer communication networks which incorporate cable and radio links.
- Provision of network analyses and designs to meet the requirements of the constantly expanding ARPANET.

The research program has led to computational breakthroughs for a number of fundamental network problems including shortest path and shortest tree problems and network reliability analysis. These developments have been, in turn, incorporated in heuristic design procedures to increase the size of tractable network problems. Our reliability analysis advances have allowed us to study the tradeoffs between network size, network reliability, connectivity, and element reliability for ARPA-like networks with as many as 200 nodes.

Current research is aimed at developing new analysis and design procedures that will allow networks with several thousand nodes to be tractable.

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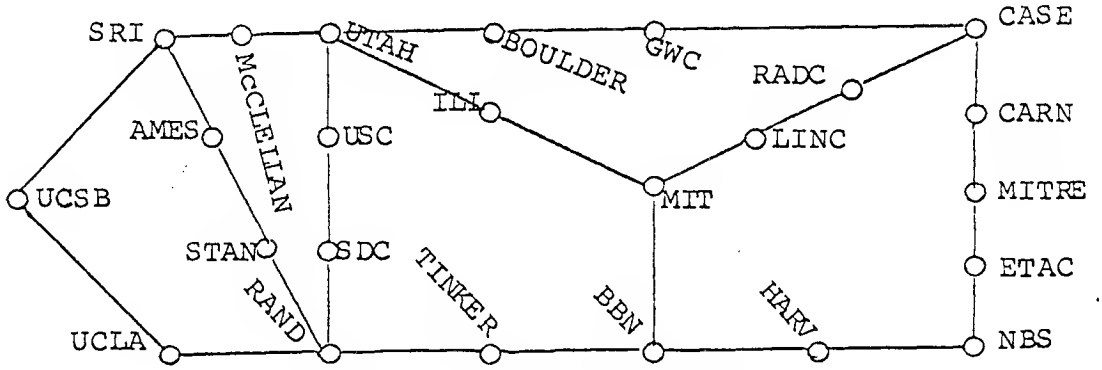
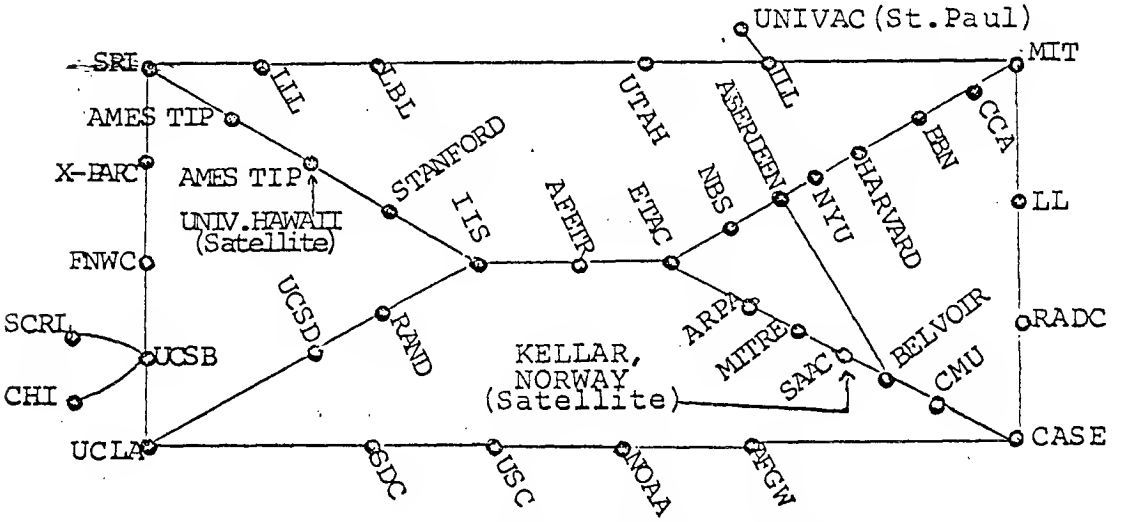


The ARPA 24-Node Network



The Projected Early 1973 ARPA Network

Bolt Beranek and Newman Inc. NIC #13544
ARPA Network Contract

Principal Investigators Conference
San Diego — 8 January 1973

During the past year, the network has nearly doubled in number of nodes and has experienced more than an order of magnitude increase in daily traffic. Along with this general growth several developments are notable:

- A "Very Distant Host" option now permits connection of a Host to an IMP over error-controlled common carrier circuits.
- A network circuit is operating locally at AMES at 230.4 kilobits/second.
- After detailed interaction with the network community, and considerable technical difficulty, a major software revision was accomplished which eliminated a basic design flaw called "reassembly lockup". We have continued to examine routing problems in great detail, and major software modifications in this area are planned for early 1973. Some interesting work has also been done on tools and techniques for documenting and "checking" real time programs such as the IMP/TIP software.
- As dependence upon the net increased, we shifted in midyear to a 24-hour, 7-day manning of the Network Control Center and have instituted experiments in expanding the services offered by the NCC staff.
- Major efforts were made to improve the performance and "human engineering" of the Terminal IMP. It was surprisingly difficult to satisfy the numerous demands upon the TIP, and we had clearly underestimated this problem. We believe (hope) that the user community is now reasonably happy with TIP behavior, but a significant continuing effort is required in this area. An interesting new direction is the use of network Hosts to provide increased "virtual" TIP capability; an example is the TIP "news" which is provided by an "automatic" use of BBN TENEX.
- A magnetic tape facility for the TIP was provided in the field.
- A significant effort was made to compute and measure the subnet performance and this work is being documented in our forthcoming Quarterly Technical Report.
- The ~~first~~ satellite link (50 Kb, to Hawaii) was added to the net in December 1972.
- A decision was made to increase the core storage of IMPs and TIPs to, respectively, 16K and 28K words; these retrofits will occur early in 1973.

A major thrust of the group this year has been the design of a minicomputer/multiprocessor to serve as a "High Speed Modular IMP" (HSMIMP). After considerable agonizing we decided to build this machine around the Lockheed Electronics "SUE" computer. The modular approach will provide both an IMP capable of handling megabit circuits and a small low-cost IMP version. The design is novel, involving a modular "bus coupler" arrangement of the "switch" which

interconnects processors, memory, and I/O and a special hardware technique for assigning tasks to the several processors which avoids use of interrupts. Initial components have been delivered from Lockheed, prototypes of hardware specials are under construction, detailed design is in progress, programming has begun, and an initial operating prototype multiprocessor will exist in mid-1973. The first version of the High Speed IMP is planned to include fourteen processors. As an interesting sidelight, the cards for a single processor (without cage, memory, power, console or steering wheel) cost about $900.

Another important thrust has been the study, with ARPA and others, of techniques for multi-access "broadcast" use of satellite channels in the net. We developed a promising modification of the Aloha System, for satellite applications, which permits low delay and efficient channel utilization with simple and fail-safe algorithms. We are participating in the study of this approach and other similar approaches, and initial design choices will probably be made in early 1973. The system choice is of some importance because this kind of communication might become a significant factor in global data communication.

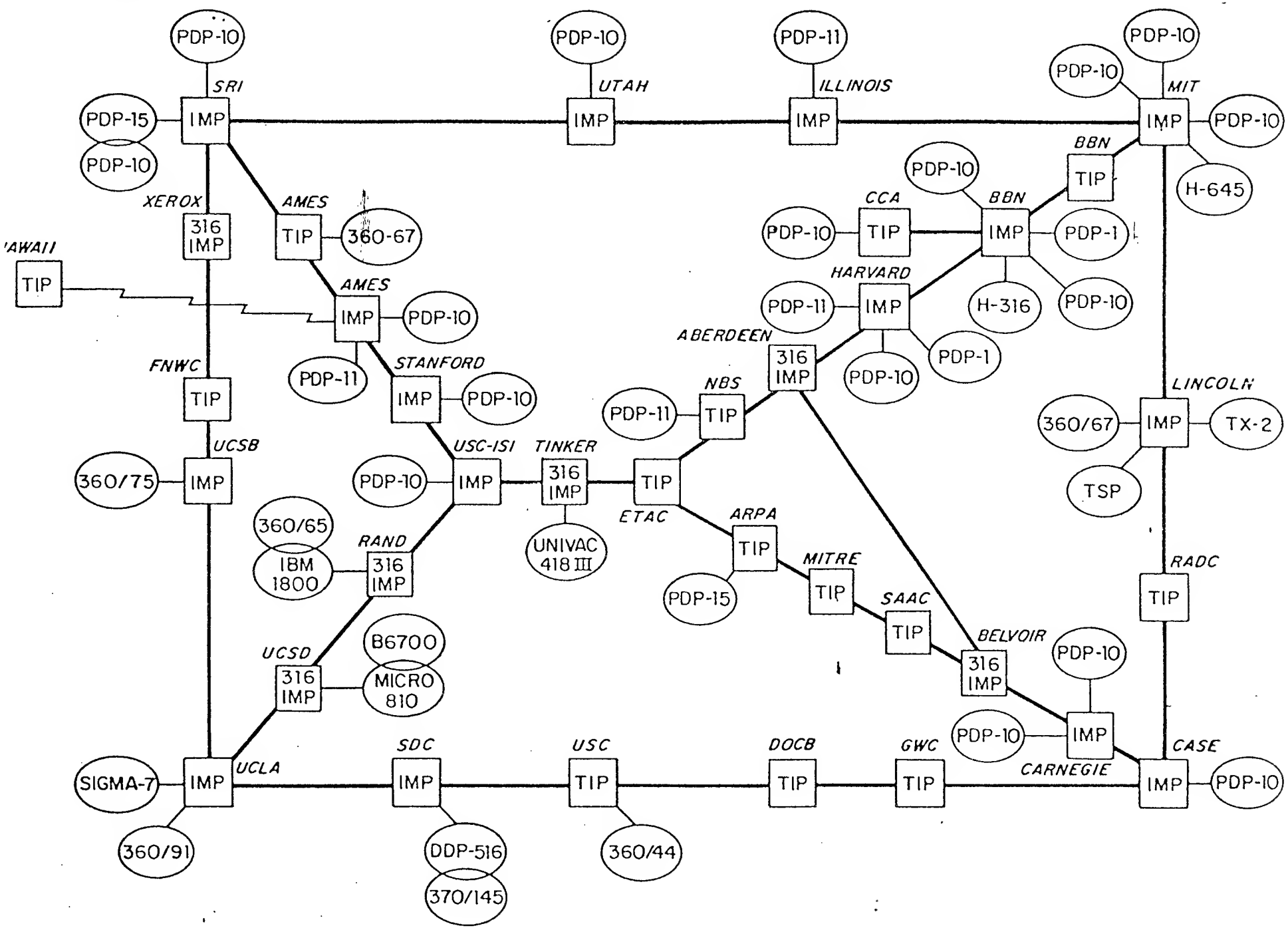
We are providing a separate three-IMP, one-room version of the ARPA Network to the Defense Communications Agency (DCA) for trial studies in the connection of "WWMCCS" computers. This sub-project is somewhat confused but we are making serious efforts to help the DCA mount a useful experiment.

We have continued and escalated our participation in Host-protocol development and documentation, and recently began participating in international discussions on this set of issues. We also have increased our support of Host network utilization by providing a "Host-Software-Consultant" as part of the Network Control Center on an experimental basis.

Documentation, participation in conferences, and the handling of interested visitors has been a significant effort this year. In addition to major revisions to existing manuals and several new manuals, the following formal papers were written: "The Network Control Center for the ARPA Network" for the ICCC, "Improvements in the Design and Performance of the ARPA Network" for the 1972 FJCC, "Terminal IMP Experience and Improvements" for the 1973 IEEE CONCOMP, and "Reservation ALOHA" for the 1973 Hawaii System Science Conference. An unexpectedly large effort was required to support the ARPA Network demonstration at the 1972 ICCC, but the demonstration was quite successful and created significant interest.

Frank E. Heart
1 January 1973

NIC #13544


PDP-10
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IBM 1800
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MICRO 810
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316 IMP
DOCB
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GWC
TIP
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PDP-10
IMP
CARNEGIE
LINCOLN
360/67
IMP
TX-2
TSP
RADC
TIP
CASE
IMP
PDP-10

COMPUTER NETWORK RESEARCH

(1972 Summary)

UCLA
January 8, 1973

Leonard Kleinrock
Principal Investigator

The principal activities at UCLA have continued to focus on: the performance evaluation of computer systems (in isolation as well as in networks); the network measurement facility; and the study of packet switching in satellite and ground radio communication systems. In all of the studies, we are confronted with conflicting demands placed upon the resources of finite capacity systems, and our goal has been to understand the dynamics of these conflicts and their effect upon throughput, performance and cost.

1. Our basic (successful) approach to the analytic performance evaluation of computer systems has been to study probablistic models of the demands and system behavior. We have in the past developed rather extensive models of single resource computer systems. Our current research also extends into modeling multiple resource computer systems which permits us to include, not only competition for the CPU, but also that for the core memory, drums, disks, transmission channels and terminals. These mutliple resource computer systems models are also prime candidates for computer network studies. We are interested in evaluating the validity of these models by measuring the behavior of real computer systems. This requires that we gain access to some representative operating systems in a way which permits measurements of certain critical parameters to be made; we expect to gain this access through "cooperative" hosts on the network. In addition, we have been making use of simulating programs to test the validity of these models.

   We have progressed significantly in the area of computer network modeling. We have developed an efficient algorithm for optimally assigning flow in computer networks and also have found optimal capacity assignment algorithms for some classes of channel cost functions. In addition, we have identified a number of significant remaining problems in the analysis and design of these networks. Among these we include, for example, the channel capacity assignment when the channels are available in discrete sizes, the combined flow and capacity assignment problem, and the most difficult topological design problem which we have so far been successful in attacking by the means of analytically based heuristic methods. We have been studying large networks and the problems they create; in particular, we have begun to study effective means for partitioning these networks, both for the purpose of design as well as for the implementation of effective routing procedures. Among our other approaches we intend to investigate the possibility of diffusion approximation methods from queuing theory in attacking these problems.

2. The Network Measurement Center exists to provide a sophisticated measurement facility adequate for a wide variety of uses. The primary purposes are: to measure the performance and usage of the network; to test the limits of the network; to provide a means

for validating and improving our mathematical models; to make some long term measurements in order to refine our models with regard to the statistical properties of the network message flow; and eventually, perhaps, since it is planned for the network to be sold to some other agent which will then presumably lease network use back to ARPA, it is therefore necessary that we at the Network Measurement Center provide a set of specifications which must be met by any future owner of the network.

We have expanded the capabilities of our network measurement program. This includes the cooperation of certain hosts in the network who have agreed to permit us to place tools within their Network Control Program so as to provide such facilities as traffic reflectors and remote data gathering. We have conducted network limit experiments including the "RAND Saturation Experiments" in which we successfully (?) deadlocked the network at will. Our tasks also include such as the conducting of experiments on packet-switched speech and its behavior in the network. We also intend to analyze the effect on speech of different buffering methods to compare the tradeoff between smoothing and delay in these speech transmissions.

3. A major new effort has emerged in the last few months with regard to packet-switching in satellite and radio communications systems. We already have some students and faculty busy at work analyzing and simulating these systems. In the satellite case, a basic problem is to resolve the conflicting and simultaneous access to a wide band channel by effectively controlling the use of this channel; the difficulty is that the control information must also pass over the satellite channel which is itself under conflict. In the case of ground radio packet-switching, problems are rather different in that the capture effect due to distant-dependent reception is of prime importance. In addition, the mobility of the small terminals making use of the radio communication channels introduces some interesting problems. Here, too, simultaneous access and conflict under unpredictable demands is the basic issue. Effective routing and control procedures must be studied here. Analytic and simulation models will be taken advantage of in this case.

   The ARPA Network will shortly include some satellite channels both across the Pacific and the Atlantic Oceans. Along with our analytic and simulation studies we intend to use our network measurement tools in studying the effect of satellite communications on network behavior. These measurements will permit a rather immediate assessment of the effectiveness of multi-access satellite communication.

BBN Computer Science Division

ARPA Activity Summary - 1972

Speech Understanding

BBN's method for developing a speech understanding system involves identifying distinct system components which are initially simulated by human beings and as we learn how are subsequently implemented by computer programs. This incremental simulation approach provides valuable insight into the essential nature of the speech understanding problem, forms a basis for the design of the individual components of the total system, and helps to identify communication and interfacing requirements between the system parts.

So far, our system includes the following components: an acoustic processing front end, a word matcher and retriever, a bookkeeping module, components specializing in syntax, semantics, and pragmatics plus a control module for directing the interplay of all components. Some of these components are still implemented by humans - in particular the front end acoustic analysis module, the executive/control, and the bookkeeping functions. However the lexical analysis and word matching functions have been computerized. Implementation of a syntax analyzer and semantic network suitable for spoken input are progressing well. The syntax analyzer has backward and forward parse capabilities and can remember all interim paths which is important for parsing spoken input with word or segment ambiguities. We are very near to having an automatic front end based on linear predictive signal analysis which can propose segments and recognize segment boundaries.

BBN hosted a speech seminar on Acoustic-Phonetic Characteristics of English sentences Dec. 3-6 for the members of the Speech Understanding Research Community. For those who could not attend, a video-tape of the proceedings is on a tour around the country.

BBN's speech activities have used the ARPANET in several areas. We have attempted to augment interpersonal communication among the Speech Understanding contractors by utilizing message handling procedures and services via the ARPANET. We are also using an A/D converter at Lincoln Lab to digitize speech and transmit it to BBN. Our lexical analysis and word retriever module will soon be available to other contractors over the ARPANET.

Distributed Computation

Our work on TENEX development has evolved into a project to explore a distributed TENEX-based operating system. Ultimately, a user at any ARPANET access port could log into the distributed TENEX system which will perform his computation and store/retrieve his files at the TENEX site(s) most consistent with user criteria, such as rapid accessibility, high reliability, and quick response time.

As a first step, we have created an experimental Resource Sharing Executive system (RSEXEC) which operates on a number of the TENEX Hosts on the network. The RSEXEC enlarges the range of storage and computing resources accessible to a user to include those beyond the boundaries of his local system. It includes a command language interpreter which extends the effects of user commands to include all TENEX systems in the ARPANET (and for certain commands some non-TENEX systems) and a monitor call interpreter which provides user programs with a virtual machine that extends beyond the local system. By acting as an intermediary between the user and non-local systems the RSEXEC removes the logical distinction between files and devices that are local and those that are remote. Within the RSEXEC environment, neither the user nor his programs need deal directly with (or even be aware that they are dealing with) the ARPANET or the remote systems.

TENEX itself is evolving to a more capable base system with the planned addition of such features as a monitor call trap-to-user capability (to enable user simulation of monitor calls), better multi-job/multi-process debugging tools, support of dual processor configurations, support of a more general file directory structure, and redistribution of the system peripheral and file storage devices to peripheral computers for increased accessibility and reliability.

Preparations for the Special Project demonstration at the International Conference on Computer Communications consumed considerable effort and included the preparation of a film on Resource Sharing Networks now available. The Conference demonstration itself was a unique experience for all of us who participated.

The BBN-TENEX Research Computer Center continued as an active host installation on the network providing BBN and network users with reliable computer facilities. The year's experience with serious network use has helped to improve the operation and efficiency of TENEX network programs.

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NIC 13567
4 January 1973
Keith W. Uncapher

The USC-Information Sciences Institute was founded in April 1972 as part of the University of Southern California's School of Engineering. Since then, ISI has created a major center for computer science research in areas of national concern. The ISI facilities are located at Marina del Rey, California, and include office space for some 30 full-time professionals, a major TENEX installation, lab and model shop facilities. ISI participates in the academic program at USC in several ways, including involvement of faculty and graduate students in the research programs at the Institute. For the most part, however, the Institute is staffed with full-time professional research personnel. The Institute has several program elements concerned with national defense supported by ARPA as described below.

Automatic Programming. (R.Balzer). The Automatic Programming Project is studying methods for significantly reducing the effort needed to get a task performed by a computer. Initially, this project has produced and distributed a draft of a state-of-the-art paper which discusses completed work, work in progress, and future plans in the area. This work is intended to help ARPA focus a national program with a working definition of the area of Automatic Programming. This investigation is currently exploring alternative goals for such systems and identifying key technical problem areas.

Among the areas of required development defined in the report, ISI is investigating that of "Problem Acquisition." We intend to investigate the acquisition of models of problem domains from natural language discourse with the user and their use in task performance for those domains.

Software Assurance. (R.London, R.Bisbey). Three areas of research are being pursued under this project. The first is a survey of contemporary operating systems to characterize them in a security sense, to identify their strengths and vulnerabilities, and to develop an empirical methodology for discovering security flaws in future systems. This work has resulted in the identification of major security problems in several operating systems previously thought to be secure, and the compilation of a comprehensive list of both specific and generic problems found in contemporary systems.

The second area of research being undertaken is the formalization of issues relating to protection in operating system design. The goal of this work is to identify the necessary elements of a protection mechanism and to develop a formal methodology for characterizing and modeling various protection schemes and for evaluating them with respect to sufficiency.

The third and final area of research is in program verification. This work involves the development of an automated program verification system with which the author of a computer program can interactively submit the source code of the system augmented by assertions to be proven about the code. The output of the system would either be a formal proof of assertions or a description of why the assertions cannot be proven.

Advanced Automated Evaluation (R.Anderson). The purpose of this program element is to: (1) evaluate the technological feasibility of significant advancements in computer-based automation of discrete product manufacture; (2) evaluate the economic impact on DOD and the U.S. economy derived from implementation of those advancements; (3) define the development program required to achieve those advancements, areas to be addressed and resources required; (4) perform R&D on innovative solutions for some components of the development program.

Documentation of this project's findings to date are contained in three ISI research reports and a recently-completed film report. We will present a major briefing and report to ARPA at the end of April on technological feasibility, economic impact analysis, and the proposed development program in computer-based automation. We expect this briefing to help ARPA form a basis for an integrated, long-range ARPA program in computer-aided manufacturing technology.

Network Supporting Research. (J.Heafner, R.Parker). We have recently been engaged in three network activities. The largest of the three is a study of the effects of a packet-switched network on continuous speech signals in interactive communicotion. This project, just getting started, will develop woys of partitioning ond reconstructing voice stream signals to provide the appearance of real-time. The project personnel are now moking modifications to an IC-4000 computer which is on the premises. This configuration will be used for initial in-house experiments using full bandwidth signals, while simulating the characteristics of present and possible future packet-switched communication facilities. We will be studying the processing requirements implied by humon factors considerations and communication system characterisitcs. We are in the process of procuring a signal processor to be attached to the ARPANET for further study. Speech compression algorithms produced by other ARPA contractors will be implemented on the machine.

The second project, just beginning, is a small, one-man effort to identify the problems of transparent networking in a heterogenous network. The problem domain is the cooperation of remote subroutines and processes.

The third activity, now completed, was the debugging of the Data Reconfiguration Service Compiler. The service is now available for experimental use of UCSB.

Programming Research Instrument. (D.Oestreicher, L.Gallenson). The PRIM Project's current goal is to create a time-shared microprogramming facility. This facility will use the TENEX system on ISI's PDP-10 and on MLP-900.

The MLP-900 is a vertical word synchronous 200 ns cycle time microprocessor with 4K words of writeable control store. Target space will be in the PDP-10 core.

The projected date for introduction of users is June 1973. At this point, users will be able to edit and compile MLP microcode in a high-level assembly language on TENEX and run these programs on the MLP. Debugging facilities on the PDP-10 and MLP will also be available. The MLP will be available to several users simultaneously on a time-shared basis.

The hardware requirements to satisfy the PRIM goals are to provide paths to target space in the PDP-10's main memory, to provide an executive mode and protected resources within the MLP, and to modify the MLP for improved performance in the time-shared environment. The interface to TENEX will be implemented and checked out by March 1973, and the additional modifications will be completed by June 1973. It is anticipated that experience with this facility will dictate additional modifications to satisfy users' requirements.

ISI TENEX. (J.Melvin). The ISI TENEX is operated as a research and service facility in support of Institute users and authorized Network users. All facilities of the time-sharing system are available to all users, independent of whether they are locally connected or remotely connected through the Network, including long-term storage and a wide variety of software.

In addition to Institute projects, the system is currently supporting the programming for approximately 150 Network users and their projects. The majority of the Network users are TIP-based. The Institute view is that the principal service to the Network is the availability of the system. All Network users are assumed to be experienced with the use of TENEX and the Network. Programming assistance, other than documentation, is not provided.

Institute Terminal System. (T.Ellis). ISI is currently defining an Institute terminal display system which we intend to implement as soon as possible (probably via subcontract), to support the ARPA research programs at the Institute. The target specifications provide for personal, general purpose terminals based on T.V. techniques capable of displaying unlimited line drawings and one to two full pages of text in a high resolution format.